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Yale University · Osborn Botanical Laboratory

BULLETIN NO. 1

Decay in
Pacific Northwest Conifers

BY

J. S. BOYCE, M.F., PH.D.

Professor of Forest Pathology, Yale University



New Haven · Yale University

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DECAY IN PACIFIC NORTHWEST CONIFERS*

IMPORTANCE OF DECAY

DECAY is one of the most important factors to be taken into account in the proper management of the virgin, overmature, coniferous forests of the Pacific Northwest, and in certain types the presence of decay has prevented the cutting of stands which from the standpoint of the future welfare of the forest should be exploited immediately. In spite of the fact that the overmature stands are being logged very rapidly and the peak of lumber production in this region is in sight, the subject of decay is one which will continue to be of importance for many years to come. In fact, it will even increase in importance, for now the more inaccessible and less desirable stands where the amount of defect is relatively higher are being reached, and such stands must necessarily form an increasing proportion of the cut for some years.

Certain species are particularly subject to decay. Incense cedar (*Libocedrus decurrens*) throughout all but the optimum of its range suffers extremely heavy losses. White fir (*Abies concolor*) and lowland white fir (*A. grandis*) are also subject to very heavy cull. In fact, the heavy loss in these three species has led to their classification as "inferior" species, in spite of the high value of the woods for special purposes. Incense cedar, for example, makes good pencil stock, and white fir is excellent for pulp and for boxes for easily tainted foods, such as butter, since the wood imparts no distasteful flavor as some conifers do. This prejudice has resulted in attempts in the past to formulate management plans on national forests largely to eliminate these species from the future stands. In eastern Oregon and Washington the great amount of decay in lowland white fir, the principal component of the north slope type, has virtually prevented cutting on this type which occupies extensive areas

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probably either at a standstill or retrograding in timber production. The proper treatment of this type is one of the most perplexing problems in forest management. Western hemlock (*Tsuga heterophylla*) in certain parts of its range, as in northern Idaho, is another highly defective species, while in western Oregon and Washington it is much less defective. Losses in Douglas fir (*Pseudotsuga taxifolia*), while rather high, are on the whole not comparable to those in the trees previously mentioned.

Other species are notable for their greater freedom from decay. Among these are Port Orford cedar (*Chamaecyparis lawsoniana*) in which the loss is insignificant. Western yellow pine (*Pinus ponderosa*) throughout most of its extensive range is relatively sound. Of course, judgment on the decadence of a species depends largely on the point of view. To one acquainted only with the relatively decay-resistant species, a loss of 5 to 10 per cent would seem large, but to those familiar with losses up to 50 per cent or even more in the susceptible species, such a loss would appear slight.

Besides the actual decrease in merchantable volume resulting, decay also occasions other losses, serious enough but more difficult to evaluate. Logging costs increase in defective timber, since less merchantable volume is obtained per unit of area, yet the overhead charges remain the same. Milling costs also increase, since at best an irreducible minimum of timber unmerchantable because of decay must go through the mill, costing just as much to saw as sound material, while if the woods operation is carelessly handled a high percentage of unmerchantable material may find its way to the mill. On the other hand, there is often a tendency to be too liberal in bucking out decayed logs, commonly leaving several feet of sound wood attached to them. The well-managed operation, by careful bucking and inspection, strives to get all the possible merchantable volume from a stand and to leave all unmerchantable material in the woods. Since defective stands are difficult to cruise, decay adds considerably to the financial hazards of the lumber industry, because an underestimate of the amount of decay can result in too great a capital investment for the volume of timber finally obtained.

In order that the present defective stands may be managed and utilized to the best advantage, it is clear that lumbermen and foresters must have a thoroughgoing knowledge of decay in timber. Not only is an understanding of the underlying principles of decay and

WHAT DECAY IS

its relation to timber necessary, but above all there should be a complete familiarity with the outward indications of decay in standing and felled trees. Such knowledge is particularly invaluable to cruisers and scalers. Consequently, this discussion is not intended for specialists, but for landowners, lumbermen, foresters, and forestry students.

WHAT DECAY IS

HOW WOOD DECAYS

Wood is not a homogeneous substance, but is a more or less complicated structure of elongated hollow cells. These cells have cavities varying in size surrounded by hard walls of different degrees of thickness, composed of lignin and cellulose. Lignin gives the hard, firm texture to wood, while cellulose is a soft white fiber very similar to pure cotton fiber. The long axis of most of the cells is vertical, paralleling the vertical axis of the tree. A few are arranged in horizontal series, radiating from the center of the tree, and are known as medullary rays or pith rays. The trunk or bole of a tree is composed of bark and wood. Considering the cross section of a trunk, starting on the outside, there is first the dead, corky outer bark which forms the protective covering. Next comes the living inner bark concerned with the transportation of food. Inside this is the cambium, a very narrow, almost invisible, zone of cells which by continuous division during the growing season increase the diameter of the tree. The next zone is the living sapwood which also functions in the transportation of food and water. The sapwood forms a white or light-colored band from one half to several inches thick, usually readily distinguished from the darker-colored dead heartwood, although there are a few trees, such as Sitka spruce (*Picea sitchensis*), in which it is more difficult to separate the two. The function of the heartwood, which occupies the entire center of the trunk, is mechanical support. The cambium is continually adding new living cells to the outside of the sapwood, while those on the inside of the sapwood continue to die and add to the heartwood. An examination of the heartwood and sapwood will show that it is made up of a series of concentric rings, and in the temperate zone each ring normally represents a year's growth. The inner, lighter-

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colored portion of each ring is the spring wood, consisting of thin-walled cells with large cavities developed in the spring and early summer for the quick transportation of food and water, while the outer, darker portion is the summer wood, composed of thick-walled cells with small cavities developed later in the summer for mechanical support. The contrast between spring and summer wood in a species such as Douglas fir, where the two are sharply delimited, is striking, but in other woods where they merge into each other it is not so apparent. Sitka spruce is an example of this.

Decay is caused by wood-destroying fungi. The fungous plant consists of exceedingly fine threads known as hyphæ which can not be seen by the naked eye unless they occur in mass. Collectively the hyphæ are termed mycelium, and a closely woven, felt-like mass of hyphæ is known as mycelium felt or sheet (figure 18). The hyphæ feed on the substances composing the cell walls of the wood. They use certain constituents of the cell walls, neglecting others, with the result that the cell walls are broken down, the wood being thus greatly weakened and more or less destroyed. It is the breaking down of the wood and the change in its physical and chemical properties that is termed decay. Nearly all the wood-destroying fungi causing decay in living trees confine their activities to the dead heartwood and can not attack the living sapwood. Furthermore, fungi require a balance between air and moisture to cause decay. Dry wood can not decay. In fact there must be about 20 per cent of moisture in wood based on oven-dry weight before rot can begin, and 27 to 33 per cent or more is needed for decay of consequence. On the other hand, completely saturated wood can not decay because air is essential to fungous growth and activity.

STAGES OF DECAY

There are various stages in decay as the wood is changed from a sound to a completely decayed stage. In the earliest stages the wood appears to be hard and firm, the only evidence of infection being a slight color change from the normal. This is known as advance decay, early decay, or incipient decay. In some cases there is not even a variation in color to indicate the presence of incipient decay, which is then known as hidden decay. Incipient decay and

WHAT DECAY IS

hidden decay are quite dangerous since they are easily overlooked, and in some types of rot the wood is already seriously weakened in these stages and should not be used where strength is required. Furthermore, certain decays continue to develop in sawed lumber under favorable conditions, consequently placing wood with incipient decay in use where durability is needed may result in unusually rapid deterioration. Then too, the discolorations indicating incipient decay are easily confused with harmless discolorations or color variations, resulting in degrading or culling perfectly sound wood. A knowledge of color variations in wood is necessary for intelligent scaling and grading, but for this information the reader is referred to another publication (2).

After the incipient stage is passed the wood becomes more and more noticeably affected, until it is finally changed completely in appearance and structure. This stage is known as typical decay, final decay, late decay, or advanced decay, and the strength of the wood is so reduced that it can be crumbled between the fingers or easily broken. The destruction may even go so far that the heartwood breaks down completely, leaving large hollows in the tree with only the relatively thin layer of sapwood to serve as support.

In a decaying trunk all stages of decay are present, passing vertically up or down the tree from advanced decay, where the fungus has been at work the longest, through incipient decay to sound wood. The same progression may be seen on a cross section passing from the center of the decayed portion of the heartwood to the sapwood. Vertically, incipient decay may extend a few inches to many feet beyond advanced decay, varying with the individual tree and the species of wood-destroying fungus.

TYPES OF DECAY

In their effect on the wood there are two broad classes of wood-destroying fungi. The first removes more lignin than cellulose from the wood, finally leaving the cellulose as white pockets or streaks of varying size separated by areas of firm, strong wood. Incipient decay caused by these fungi does not greatly weaken the wood, and it can still be used for purposes where high strength and durability are not required. Conk rot, or red ring rot, caused by the ring scale

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fungus (*Trametes pini*) so common in Douglas fir, is a typical example of this type of delignifying decay or white rot (figures 8 and 9). The second class removes more cellulose than lignin, finally leaving the wood very much lighter in weight and reduced to a carbonaceous mass, in varying shades of brown, so that it can be crumbled into powder between the fingers. Wood with advanced decay of this type is utterly worthless for any purpose, and even with incipient decay it is greatly reduced in strength. Hidden stages are also common with this type of decay. Red-brown butt rot caused by the velvet top fungus (*Polyporus schweinitzii*) typifies the carbonizing decays or brown rots (figure 19) to which the name dry rot is often loosely applied. Sometimes the two types work in the same tree, a white rot attacking the heartwood first and then being followed by a brown rot which destroys the remaining relatively sound wood between the cellulose pockets. The delignifiers never follow the carbonizers, however. A German pathologist has proposed the terms "corrosion" for the delignifying and "destruction" for the carbonizing decays.

Based on the final effect of decay on the wood are many descriptive terms which are not typical of any one decay but describe a group, such as pocket rot, pin rot, or pecky rot. These are carbonizing decays which occur in definite pockets separated by firm wood. Piped rot indicates a decay occurring in streaks separated by seemingly sound wood, and ring rot indicates that a definite group of annual rings extending partly or entirely around the tree is decayed. Dry rot, the most widely and at the same time loosely applied term of all, is something of a misnomer, since dry wood can not decay. Again, color is often used in the name, as red rot, red ring rot, or red-brown butt rot. Decays are often described according to their position in the tree, as root rot, butt rot, or stump rot confined to the base of the tree, trunk rot extending throughout the trunk, or top rot confined to the tops. However, too much importance should not be attached to such names, as it is not unusual to find a decay, normally confined to the base of the tree, in the third or fourth log, while top rots may occur in the butt. Butt and root rots are more important than is indicated by the volume of wood destroyed. Butt rots decay the most valuable wood in the trunk, while together with root rots they predispose infected trees to wind-throw.

WHAT DECAY IS

HOW DECAY SPREADS

After decay has been at work for some time the fruiting bodies, sporophores or conks, develop. These, which are usually quite large, appear on the trunk or on the branches in the form of brackets (either flat or hoof-shaped) and crusts, or on the ground near by coming up from a decayed root in the shape of toadstools. In rare cases the mycelium forming the conks issues directly from the heartwood through the bark, but ordinarily it finds its way out through wounds or, most common of all, through dead branch stubs not yet grown over or occluded. The conks are either annual, living for one season only and then being destroyed by birds, rodents, and insects, or perennial, living for a number of seasons. The annual conks are usually soft and mushy or somewhat leathery when living, while the perennial ones are hard and corky or woody. The variously colored upper surface may be smooth or rough. In perennial conks it is more or less zonate, each zone roughly corresponding to a season's growth. On the undersurface are the gills, spines, or pores, the latter being most common. These pores vary in shape from tiny and perfectly circular ones to large and irregular ones. Figure 1 shows the rough, blackish upper side and the irregular pores on the underside of a sporophore or conk of the ring scale fungus. In the pores or on the spines and gills are borne the spores which are microscopically small reproductive bodies of very simple structure. It has been estimated that a single sporophore of the annual type will produce from 50 to 100 billion spores in the course of a year, and a sporophore of the perennial type may discharge 682,200,000 spores in one week (6, pp. 84 and 85).

These myriads of tiny spores are easily carried by the wind and, alighting in a suitable place, germinate by sending out tiny hyphæ which institute decay. The hyphæ can not penetrate bark or living sapwood; consequently a spore must light on exposed dead wood directly connected with the heartwood for decay to result. But there are numerous points of entrance. All the dead branch stubs form bridges from the outside to the heartwood, as does the exposed dead sapwood where the bark has been knocked off by injuries. Broken tops give direct access to the heartwood, as do fire scars when the fire has eaten deeply enough into the tree. As soon as a wound occurs the tree immediately begins the healing over process, but this

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of course is very slow, requiring years, as does the growing over of dead branch stubs. Meanwhile the tree is exposed to infection. The more highly resinous of the conifers quickly cover the smaller wounds with pitch which acts as an excellent antiseptic dressing to prevent the germination and growth of spores, but very large wounds can not be protected in this way. After decay has once started it is usually only a question of time until sporophores appear and more spores are released to infect other trees. It is apparent, though, that only an infinitesimal number of the spores produced ever cause infection in another tree. If any significant portion of them found their mark, practically every overmature tree would be decayed.

INDICATIONS OF DECAY

A KNOWLEDGE of the indications of decay in standing trees and in logs is absolutely essential for intelligent cruising and scaling, yet on this subject there is an enormous amount of misinformation, and the judgment of defective timber is often considered to depend on some kind of second-sight. Actually, an experienced woodsman can soon learn the indications of decay and how to apply this knowledge intelligently. All decays give some indications of their presence in a stand, while some, like the most common decay in Douglas fir, rarely ever cause appreciable rot in a single tree without indicating their presence to a skilled observer. Yet it is a common sight in the Douglas fir region to see, on the one hand, completely decayed trees felled and, on the other, partially or completely sound trees left standing because they were thought to be rotten (figures 3 and 4). Most companies, instead of making one trained man responsible for deciding whether trees should be felled or not, leave this to the fallers with uncertain results, since there are common abnormalities on trees which, though often so considered, have nothing at all to do with decay. Some years ago one large operator in Douglas fir logged a half section, leaving a large number of trees standing as decayed on the judgment of the fallers. Within a short time there was a change in woods management and it was decided to log the remaining trees on the same area. The result was only approximately 4 per cent less log scale obtained from the supposedly decayed trees than from the presumably sound ones first cut. Another company, in building a railroad right of way, had to fell a number of trees

INDICATIONS OF DECAY

which had been left standing, because they were considered completely decayed when the stand was logged several years previously. Many of these so-called decayed trees were sound when felled. Both these companies then went to the other extreme and felled all trees. This resulted in increased logging costs, since completely unmerchantable trees were felled and sometimes partially bucked. Furthermore, the decayed trees, if left standing, would have served as seed trees if an operator were considering a perpetual cut, since in the Douglas fir region the danger of spreading decay to the future stand from decayed seed trees is reduced to the minimum (1). However, in other regions, leaving decayed trees for seed trees is very poor practice.

The most important and certain indication of decay is, of course, the presence of sporophores or conks, but it is also necessary to distinguish between the different kinds of conks to evaluate properly the amount of decay indicated in the tree. Some decays develop conks very abundantly, starting shortly after the fungus has begun its work in the heartwood, while others only develop occasional or rare conks after extensive decay has occurred. A single conk of one species may normally represent only a few board feet of decay, whereas one of another species may mean that the entire merchantable volume of the tree is destroyed. The conks of the velvet top fungus, causing the most common butt rot in this region, are usually found not on the tree but on the ground near it, coming up from a decayed root, yet a conk in that position is a sure indication of decay in the tree, usually confined to the first log. Other conks are those of fungi which can not decay the heartwood of living trees but grow only on dead sapwood, so that the appearance of these on a wound on a living tree means only a superficial decay of no consequence.

Just as good an indication of rot in a tree as conks themselves are the signs that conks have been present or are developing. Fragments of an old conk may be found still attached to the trunk or lying near the butt of the tree, the bark may be discolored at the point of attachment, or a hole may be left by the rotting branch from which the conk appeared. Swollen knots on Douglas fir and other species caused by the ring scale fungus and shot-hole cups on incense cedar (*Libocedrus decurrens*) are still more enduring outward records of rot in the heartwood. Then, too, by chopping into

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knots the characteristic decay often becomes apparent, or in some cases the same color or the same substance is present as may be seen when a conk is cut open. These rotten knots with the same substance as the interior or context of the conk are known as punk knots when no swelling of the surrounding wood results. In case there is a swelling, they are termed swollen knots.

Scars of all kinds are excellent clues to decay. Butt rots are commonly associated with fire scars. In Douglas fir, for example, nearly all trees with fire scars have butt rot. It is possible for years afterward to pick out trees with such scars completely healed over, because the bark has an abnormal appearance, the regular arrangement of the ridges being interrupted. Swollen or churn-butted Douglas firs commonly have butt rot, because the abnormal shape comes from healing over a fire scar. Broken or dead tops are common points of entrance for decay, and a slight, sharp crook in a trunk indicates a broken top of decades ago which has long since been grown over, but which nevertheless was an entrance for infection for a number of years. Large branches broken off by wind, snow, or ice storms, or other agencies often reveal decay in their heartwood, showing that the trunk is also decayed. To become thoroughly familiar with the actual amount of defect indicated by the various signs of decay, the cruiser or scaler must spend a great deal of time on the mill deck studying the defective logs as they are sawed. Only in this way is it possible to become thoroughly familiar with decay in any region. For instructions on scaling defective timber the reader is referred to two publications (10 and 11) and to a manual by Hubert (9) which gives detailed information on decay and its indications for the commercial species of the Inland Empire region.

Pounding on the tree, while a fairly accurate method of determining the presence of some decays, for example, the brown rots in small, rather thin-barked timber, has less value in the overmature stands in this region where the bark of all species, but particularly of Douglas fir, is so thick that it deadens the sound and also makes it time consuming to remove the bark to obtain a solid sounding place.

In addition to the actual indications of decay there are other abnormalities that are often confused with them. One of the most

RATE OF DECAY

common is burls. These conspicuous swellings found on most conifers in varying degree are not connected with decay, but are a disorganized mass of woody tissue with a gnarled or twisted grain, often formed as a direct response to the irritation caused by an injury, particularly a bruise, and may be likened to the formation of tumors on animals. Figure 2 shows a sound Douglas fir left standing on a logging operation, because it was thought that the burl indicated extensive decay. A tree much larger than the average in a stand and with many dead limbs in the lower crown is not necessarily decayed. Such specimens, known to foresters as "wolf trees," have merely grown faster than their neighbors, and the limbs did not die so quickly from lack of light, thus requiring a longer time for the dead branches to break off and for the branch stubs to heal over. A variation in the character of the bark rarely indicates decay unless, as explained before, the change indicates an old, healed-over scar. Abnormalities in branching, such as the branch "fans" on Douglas fir or the "candelabra" limbs on incense cedar, are never connected with decay, although abnormal top branching is often the result of dead or broken off tops through which decay frequently enters.

RATE OF DECAY

THE rate of decay in timber must be considered from two viewpoints, that is, in individual trees and in stands. Economically the latter is all-important.

There is very little known as to the rapidity with which decay works in individual trees, because this information is exceedingly difficult to obtain. The only way the volume of decay in a tree can be exactly measured is to fell the tree and split or saw it open. Then if the exact year in which infection occurred can be determined, an average figure for the yearly increase can be obtained. But it is extremely hard to determine just when decay entered a tree, and if artificial infection is attempted, many years must elapse before the result can be secured. Experiments of this kind have so far produced no results of consequence. In Germany (15) decay in the heartwood of oak caused by the false tinder fungus (*Fomes ignarius*) varied from .12 to 1.23 feet in yearly progress, with an average of .16

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to .30 of a foot. There was no real difference in the upward and downward rate of spread from the point of infection. Decay in incense cedar caused by the incense cedar fungus (*Polyporus amarus*) was found to vary considerably in rate of development. In the heartwood of the tree in which decay developed most slowly, the average yearly vertical progress was only between .002 and .003 of a foot, but in the tree in which it developed most rapidly, its progress was between the limits of .53 and 3.09 feet yearly. In general the minimum progress of decay varied from .01 to .20 of a foot a year, while the maximum ranged from .01 to .35 of a foot (4, p. 21). These figures were determined by connecting the focus of decay with a single wound healed over. By determining the age at which the wound occurred and the number of years elapsing before it healed over, the minimum and maximum length of time the decay had been in the tree could be fixed, and then the average possible minimum and maximum yearly progress of the rot determined. From the foregoing figures it can be judged that, in general, decay in living trees is probably a rather slow process.

In the past there have been very little exact data on the rate of decay in stands, but plenty of surmises. There is a general tendency to estimate decay as progressing much more rapidly than it actually does, and this has been particularly true of late years when stumpage has been increasing in value and standards of utilization have been becoming higher. It is natural that a reëxamination of a defective stand after a 5 to 10-year interval should often seem to indicate a large increase in the loss through decay. As a matter of fact, decay normally works so slowly even in a mature or over-mature stand that little or no difference could be detected in this time, except by very detailed cruises in which the same trees were included in both cruises and the amount of decay estimated by individual trees. What usually has happened is that in the years intervening between the first and second examination of a defective stand the observer has learned how to judge decay in standing trees more accurately and has adopted more rigid standards of utilization. All of the increased cull in the stand is then attributed to the progress of decay, whereas only a small portion of it should be charged to this cause and the remainder to the factor of variation in personal judgment.

Studies on the increase in volume of decay in cubic feet have

DECAY IN DOWN TIMBER

been made for several western species, notably, incense cedar and white fir in California and western white pine (*Pinus monticola*) in Idaho. It was found that all these species were sound in their youth and became more and more decadent with increasing age. The maximum increase in decay in incense cedar occurred between 223 and 259 years, when the total increase amounted to 22 per cent in the 36-year period, or .6 per cent annually (4, p. 35). The average maximum yearly increase for white fir was .55 per cent between 290 and 330 years (14, p. 68) and for western white pine, .32 per cent between 131 and 180 years in the bottom site (18, p. 8). These figures do not accord with the type of statement based on surmise to the effect that this or that stand has decayed 20 per cent in the last 5 years. The foregoing figures for incense cedar and white fir were based on the study of individual trees presumably representative of the uneven-aged stands in which they occurred. The western white pine figure was obtained from the study of all trees in the stand over definite areas.

A study by the writer of decay in Douglas fir in western Oregon and Washington, the results of which have not yet been published, showed that in the most severely decayed stands the maximum rate of decay based on the gross board foot volume of the stand was 23.1 per cent from 300 to 350 years, or .46 per cent a year, but for the average stand amounted to about .29 per cent a year from 400 to 450 years. Of course when a Douglas fir stand is breaking up and being replaced by hemlock, the loss in Douglas fir is very probably more rapid than the figures given above, but under such conditions sound or relatively sound trees drop out along with the highly defective so that the loss can not be charged entirely against decay.

DECAY IN DOWN TIMBER

TIMBER felled and left too long in the woods or windfalls which can not be logged within a reasonable time will suffer loss from decay. The decays attacking down timber do not work principally in the heartwood as do those in living trees, but first attack the sapwood and in some cases are confined to it. Others, after destroying the sapwood, rot the heartwood. The decays in living trees may continue to develop under favorable conditions after the trees fall,

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but the most damage to down timber is caused by other species of wood-destroying fungi.

A study (3) of deterioration in wind-thrown western red cedar (*Thuja plicata*), Douglas fir, Sitka spruce, silver fir (*Abies amabilis*), and western hemlock showed that during the first season the trees were down there was no evidence of decay, any loss in the sapwood up to then resulting from blue stain, ambrosia beetles, and checks. In the second season, although scattered patches of white fungus mycelium appeared between the bark and the wood, the sapwood remained free from all but occasional small spots of superficial decay. During the third season, however, there was some decay in the outer layers of sapwood, which by the fourth season had increased to a considerable extent. During the fifth and sixth seasons the entire sapwood of all species was involved, and heavy inroads had been made on the heartwood of the non-durable species. The sapwood of all down trees is very susceptible to decay, but while the heartwood of Sitka spruce, western hemlock, balsam firs, and western yellow pine is scarcely more durable than their sapwood, that of Douglas fir is quite resistant to decay and that of the cedars is extremely so.

The fungi causing most of the decay of down timber in this region rarely attack living trees. The red belt fungus (*Fomes pinicola*) and the shelf fungus (*F. applanatus*), which destroy both the sapwood and the heartwood, are the most important of the many fungi attacking silver fir, western hemlock, Sitka spruce, and Douglas fir, while western yellow pine is most affected by the ray rot or western red rot fungus (*Polyporus ellisianus*). In New Mexico and Arizona this last-named fungus causes a common rot in living western yellow pine (12), but has been found only occasionally in living trees in the Pacific Northwest.

STAINS AND DISCOLORATIONS

THERE are stains, discolorations, and color variations from the normal wood which do not weaken wood, but at the worst merely make it unsightly. However, these discolorations are often mistaken for the incipient stage of decay, causing otherwise perfectly sound wood to be degraded or rejected; therefore, information on this subject is necessary for intelligent scaling and grading. For a discussion

STAINS AND DISCOLORATIONS

of stains in wood the reader is referred to another publication (2, pp. 17-30).*

Heartwood of certain species is subject to color variations, the causes of which are as yet unknown, but which do not alter the mechanical properties of the wood. The normal red heartwood of young Douglas fir, known as red fir, is familiar to woodsmen, as is also the yellow color of the outer heartwood in old, overmature trees known as yellow fir. But it is not uncommon to find streaks or zones of the red-colored wood in the yellow fir. Seen on the end of a log, these zones of red color extending completely or partially around the log are confined more or less closely to a definite series of annual rings. In this way the color can be distinguished from the incipient stage of decay, particularly red ring rot with which it is often confused, since the latter is usually irregular in outline and has, even in the initial stages, a more purplish tinge. The heartwood of Sitka spruce, normally with a light reddish tinge, has at times a pronounced reddish or brownish pink color, which is in striking contrast to the white sapwood. The heartwood of sugar pine (*Pinus lambertiana*) and western white pine is sometimes pink, light red, or vinous red in color. The brown heartwood of incense cedar (4, pp. 22-24) and western red cedar sometimes has a reddish to purplish tinge which, when the trees are first felled or bucked, is very pronounced but fades gradually on exposure to light.

Sapwood with its high moisture content and food materials in the cells is particularly subject to staining after the trees are felled. Such stains are due either to chemical reactions or fungi, and are favored by warm, humid weather when they may become apparent shortly after the trees are bucked. Among the stains originating from the first cause is the brownish red discoloration frequently seen in the sapwood on the ends of incense cedar logs. The wood is not weakened by this stain.

The more common sap stains are those caused by fungi. The hyphæ of these fungi do not attack the wood substance itself to any extent, but feed on the food materials in the cells; consequently the strength of the wood is not impaired for most purposes—the only loss results from its unsightly appearance. A high moisture

*Since this paper was prepared for publication the following reference has appeared: Hubert, E. E. Sap stains of wood and their prevention. 77 pp., 35 figs. U. S. Dept. of Commerce, 1929.

DECAY IN PACIFIC NORTHWEST CONIFERS

content is necessary for the action of these fungi, so that staining is usually confined to the sapwood, although under favorable moisture conditions in such species as Sitka spruce and western yellow pine, the stains may penetrate the heartwood. Western yellow, sugar, and western white pines are subject to a rich brown to deep chocolate brown discoloration which usually appears in logs after they have been stored for some time (8, pp. 44-45). The most important of all sap stains, however, is blue stain. This grayish blue to almost black stain often develops with unbelievable rapidity in freshly bucked logs under favorable moisture and temperature conditions. The staining may be confined to a few inches at each end of the log or, if severe and of long duration, may extend throughout the sapwood in streaks of varying intensity. If the logs are attacked by ambrosia beetles there is invariably intense staining immediately surrounding the insect galleries. During periods of warm, humid weather favoring the fungus, the most effective way to prevent blue stain is to get the logs out of the woods immediately and into the mill pond or through the mill. Wood either saturated with water or air-dry can not blue stain. Western yellow pine, western white pine, sugar pine, and Sitka spruce are quite subject to blue stain, while the balsam firs, Douglas fir, and western hemlock are not so readily discolored. Figure 5 shows blue stain in the end of a yellow pine log.

If valuable logs must be stored for some time where they are subject to stain and decay, a spray treatment or end coating with chemicals should be used. In the warm, humid climate of the south a mixture of one part of cresylic acid with ten parts of kerosene, when sprayed on red gum (*Liquidambar styraciflua*) logs, has effectively prevented stain for nearly three weeks in the warm summer or for three months in the wet fall (16, pp. 4-8). The same mixture sprayed on the sides of the logs, with a mixture of one part of cresylic acid and ten parts of filled hardened gloss oil painted on the ends, gave somewhat better results. In addition, loss from end checking was practically eliminated by this end coating.

DECAYS OF DOUGLAS FIR

THE loss through decay in stands of Douglas fir in the Pacific Northwest is very large. On certain areas the cull figure may reach

DECAYS OF DOUGLAS FIR

50 per cent or more. A loss of 20 per cent in overmature stands is common, while it is only in young stands up to 100 years or so in age that the species is sound. All but a negligible portion of this decay can be attributed to four species of wood-destroying fungi. They are the ring scale fungus (*Trametes pini*), the velvet top fungus (*Polyporus schweinitzii*), the quinine fungus (*Fomes laricis*), and the rose-colored conk (*Fomes rosceus*). Of these the ring scale fungus is by far the most destructive. Measurements of over 2,600 trees of all age classes with a gross scale of over 10,000,000 feet board measure throughout western Oregon and Washington showed a loss of 17 per cent through decay. Taking this loss as 100, 80.8 per cent of it was caused by the ring scale fungus, 6.2 per cent by the velvet top fungus, 8.6 per cent by the quinine fungus, 4.1 per cent by the rose-colored conk, and .4 per cent by other fungi.

RED RING ROT

This rot, commonly known as conk rot in the Douglas fir region, is caused by the ring scale fungus and is widespread on Douglas fir throughout the range of the tree. Furthermore, it is the most common decay on conifers throughout the world in the north temperate zone.

Description of decay. The incipient decay is particularly striking (figures 6 and 7). It appears as a pronounced reddish purple or olive purple color against the red or yellow heartwood, and occasionally the color may be so deep as to appear brownish. Gradually the color fades as the distance from the advanced decay increases, until it is lost entirely. The color is often most pronounced in the outermost heartwood just where it joins the sapwood. The discolorations described are sometimes bounded by a narrow zone of pronounced red color. Wood is little if at all weakened by this incipient stage so that, for all purposes except where durability or extremely high strength is necessary, it is perfectly good. Vertically the discoloration may extend from 10 to 20 feet or rarely more in advance of the cellulose pockets, although 3.5 feet was found to be average, but, radially, discoloration in advance of the pockets is limited to 2 to 3 inches. The red heartwood of "red" fir, which is nothing but the normal heartwood of young trees, is frequently mistaken by

DECAY IN PACIFIC NORTHWEST CONIFERS

graders and scalers for the incipient stage of red ring rot, with the result that sound wood is culled or degraded.

In the advanced stage the wood has the same or a deeper color than in the incipient stage, but it is more or less riddled with spindle-shaped, somewhat pointed, white cavities or pockets running parallel to the grain and separated by apparently sound wood. In the pockets the wood has been reduced to a white, soft, fibrous mass of cellulose (figures 8 and 9). A number of pockets may merge forming an irregular-shaped area of rotted wood. In some cases the pockets may have no cellulose fibers. Seen on cross section at the end of a log the pockets are either rather uniformly scattered throughout the affected wood (figure 28) or, being confined to more or less definite groups of annual rings, merge together and result in ring scale (figures 7 and 27).

This decay is not limited to a special portion of the bole, except that it is not frequent in the butt of the tree, seeming to find conditions there less favorable for development. It repeatedly happens that in completely decayed trees, although the rot may include nearly the entire heartwood at the top of the first 16 or 32-foot log, yet on the stump the rotted area is small or almost completely lacking. On the ends of the logs the decay may be ring-shaped (figure 27), uniformly circular (figure 28), or irregular in outline (figure 7).

Indications of decay. Sporophores or conks are abundant in over-mature stands. These perennial fruiting bodies issue from the tree through knots. They vary in size and shape from bracket-like to hoof-shaped. The upper side is a dull grayish or brownish black, rough, and with approximately concentric furrows parallel to the lighter brown margins. The underside is a grayish brown or rich brown color with large, irregular pores (figure 1). When a conk is actively growing the margin is velvety and light golden brown in color. The substance of the conk is corky or punky.

In addition to the conks, swollen knots are developed. These are but the initial stage of a conk in which the substance forming the conk is growing out through a knot and hence is just as good an indication of the presence of decay as a conk. Often the conk never develops beyond this stage. Chopping into one of these swollen knots reveals a brown punky substance, the same as in a fully developed sporophore. In some cases the swollen knot is grown over by the

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sapwood and new bark so that it is necessary to chop through solid wood before the punky knot is reached. These are locally called blind conks. The swellings are caused by the living wood tissue trying to grow over the knot where a conk is being formed (figures 10, 12, and 14), and in many cases the appearance is accentuated by the growing conk actually pushing out the thick dead bark in a characteristic manner. The swelling resulting from the attempt to heal over a punk knot is very marked when contrasted with the appearance of a normal, sound knot when grown over (figures 11 and 13).

In the Douglas fir region the development of conks and swollen knots follows very closely the progress of decay in the heartwood, so it is possible to pick out rather accurately the trees in a stand affected with red ring rot (figures 16 and 17). When high up in a tree among the branches, swollen knots or even conks are not easily seen with the naked eye, but if overlooked there it does not make so much difference in accuracy of an estimate, since the scale of the top logs is insignificant in the total. It is not only possible to pick out the decayed trees, but it is also feasible to judge with some exactness the normal extent of the rot. After a careful study of a number of mature and overmature decayed trees, it was found that a closely approximate figure for the extent of the rot above and below the highest or lowest conk was 20 feet and for a swollen knot, 9.5 feet (5, p. 14), which includes the incipient decay. Although no exact studies have been made of younger trees, observation indicates that for trees less than 150 years old the extent of decay beyond the highest or lowest conk or swollen knot is about half the figures given above for older timber. Of course individual examples varied considerably from the distances stated, but these figures have proven themselves to be a good average. They should be applied only when there are several or more conks or swollen knots separated by a few feet or scattered along the trunk. If there is a single conk or swollen knot or one compact group, only one 16-foot log, or 8 feet in each direction, should be culled. By studying felled trees and then watching infected logs through the mill, it is possible to modify these limits to fit any local conditions. After a tree has been felled, it is relatively easy to estimate the extent of decay by chopping into the knots, and if in addition it has been bucked so that the ends of the logs can be seen, judging rot is even more simplified.

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It is difficult to estimate decay in fire-killed timber, but even there red ring rot can be detected. The dry, punky substance of the conks or swollen knots extending into the tree burns readily, resulting in circular holes reaching two to three inches into the trunk—thoroughly reliable indications when their significance is understood. The surrounding bark is merely scorched and blackened. Of course it is impossible to tell whether the hole was formerly occupied by a swollen knot or conk.

Since the ring scale fungus infects the trees almost entirely through knots or dead branch stubs, scars are of no importance as indicators of red ring rot.

BROWN TRUNK ROT

This rot is caused by the quinine fungus. The fungus takes its name from the extremely bitter tasting conk which was for a long time valued in Europe for its medicinal properties. The bitter taste does not extend to the decayed wood or the mycelium felts.

Description of decay. The incipient stage of this decay is difficult to detect since it appears first as an extremely faint, barely discernible, brownish discoloration, scarcely contrasting with the normal reddish or orange reddish color of the heartwood. It is preceded by a hidden stage which extends for several inches beyond the last visible discoloration. As the discoloration becomes more pronounced the wood becomes softer. Rarely incipient decay is indicated by a brilliant and intense purplish discoloration. It was found that the incipient decay might extend 8.5 feet beyond the advanced stage, but the average was 3.6 feet. The wood is seriously weakened even in the hidden stage.

In the advanced stage the wood is a brown mass, easily crumbled between the fingers. It is more or less separated into irregular-shaped cubes by cracks in shrinking. These cracks may be occupied by the conspicuous white mycelium felts (figure 18). These felts may completely fill large cracks or old wind shakes, becoming a quarter of an inch thick, a foot or more wide, and several feet long.

The decay is not confined to any particular portion of the bole. Where the rot column runs out it is roughly conical in shape; elsewhere it is more or less cylindrical. Seen on the ends of logs the rot is usually somewhat circular in outline. In the advanced stage

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shrinkage cracks along the annual rings and at right angles to them are common. Frequently these cracks are filled with the conspicuous mycelium felts.

Indications of decay. The quinine fungus has large, whitish perennial conks not common on living trees. They are either roughly hoof-shaped or long and cylindrical. The substance of the conk is white, soft, and cheesy when young, and rather crumbly and chalky when old and dry (figure 18). The upper surface is chalky white or brownish, rough and zoned, while the undersurface is white with small pores. The conks issue through knots or old wounds. No swollen knots or punk knots are formed by this decay.

On the whole it is not easy to judge brown trunk rot in standing timber. Since conks are developed only occasionally and only after decay has become extensive, a tree with a single conk must be considered unmerchantable. Broken tops are a common point of entrance for this decay; consequently in a stand where the presence of conks has shown the decay to occur, broken-topped trees are probably infected. Then the trunks must be closely scanned for large broken-off branches in which the typical decay can be seen, for a branch with decayed heartwood indicates extensive rot in the trunk. Stands so badly overmature that they are being replaced by hemlock are particularly subject to brown trunk rot. It seldom causes loss of consequence in other than very overmature timber.

BROWN CUBICAL ROT

This rot is caused by the sulfur fungus (*Polyporus sulfureus*). The decay is very difficult or impossible to distinguish from that caused by the quinine fungus, although it usually starts in the butt of the tree, entering through an old wound, and normally does not extend above the lower half of the trunk. The conks are annual, mostly appearing in the summer or fall after a rain, and develop in clusters of large, thin shelves (figure 20). They are soft, juicy, and cheesy without any bitter taste. The upper surface is orange yellow and smooth, while the smooth underside is a brilliant sulfur yellow. The pores are small. The conks are often partially eaten by rodents. When the conks dry up they commonly turn chalky white or occasionally dirty yellow and become brittle. No swollen or punk knots have been associated with this fungus.

DECAY IN PACIFIC NORTHWEST CONIFERS

RED-BROWN BUTT ROT

This butt rot, which also decays the roots, is caused by the velvet top fungus. The rot predisposes infected trees to windthrow, and it is a not uncommon sight in the spring to see large Douglas firs broken off near the ground level with the heartwood completely destroyed by this decay.

Description of decay. The incipient stage of red-brown butt rot is first evident as a faint yellowing or browning of the normal wood. This color intensifies and the wood becomes soft. A hidden stage occurs for some distance beyond the incipient stage. While the incipient stage may extend over 8 feet beyond the advanced stage, the average is about 2 feet. In the advanced stage the wood is a pronounced red-brown in color and crushes to a smooth powder between the fingers (figure 19). In the shrinkage cracks, thin, crust-like layers of mycelium are formed which are easily mistaken for resin deposits.

The rot is typically confined to the roots and butt, commonly not extending beyond the first 16-foot log, although occasionally it may extend 40 feet up the trunk. Rarely it may be found higher in the tree, localized around a dead branch stub and not connected with the butt. On the end of a log the decay is circular in outline, while the rot column as seen longitudinally is roughly cone-shaped, tapering from the butt. The following empirical rule for judging the longitudinal extent of the rot column in the butt log has been deduced from the dissection of a number of infected trees 200 or more years old. If the average diameter of the rot on the butt of the log does not exceed 4 inches, the extent of the rot up the log should be considered as 1 foot for each inch in diameter. If the average diameter is from 5 to 10 inches, deduct 1 inch from the diameter and apply the same rule. For example, in a log with a rot area of 8 inches in average diameter on the butt, the rot column should be figured as 7 feet long. In the same way, if the average diameter is from 11 to 20 inches, deduct 2 inches; from 21 to 30 inches, deduct 3 inches; and 31 inches or over deduct 4 inches. It must be emphasized that there will be many exceptions to this rule, that it is not exact for individual logs and can only be applied in scaling a number of defective logs.

Indications of decay. The annual conks which develop most abun-

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dantly just after the fall rains begin are to be found on the butt of an infected tree issuing from an old wound or, more commonly, on the ground near by, coming up from a decayed root. On the tree the conk is a thin bracket, and frequently two or more brackets grow one above the other (figure 26). On the ground when viewed from above the conk is circular in shape, sunken in the center and tapering to a short thick stalk (figure 21). When fresh the upper surface is velvety, concentrically zoned, and reddish brown in color with a light yellow-brown margin (figure 26). The undersurface is dirty green and turns red-brown when bruised. The conspicuous pores are irregular in shape. The substance of the conk is moist and cheesy. When the conks are old and dried they become corky and have a deep red-brown or blackish brown color. Swollen and punk knots are not developed.

While the conks are a positive indication of red-brown butt rot, they are to be found only on a small minority of the infected trees. The next best clue to the presence of this decay is fire scars. The majority of fire-scarred trees become infected through the scar; accordingly it is possible to judge the relative amount of decay by such trees in the stand, after the presence of conks has established the existence of the rot in a locality. Each fire-scarred tree can be considered as infected. Even though a scar has been healed over for a long time, it can often be detected by the variation in the appearance of the bark over the healed wound, which is hard to describe but not difficult to judge after a little experience. Swollen or churn butts usually indicate a fire scar or other wound long since healed. Culling 8 feet of the butt log is ordinarily a sufficient average allowance for this defect when cruising.

YELLOW-BROWN TOP ROT

This decay, caused by the rose-colored conk, occurs much more frequently on down, dead trees than it does on living ones.

Description of decay. The first indication of this rot is a faint brownish or yellowish brown color, the outer limits of which are sometimes marked by a zone of greenish brown discoloration. The yellowish brown color deepens and the wood becomes soft. The incipient decay extends about 3 feet on the average beyond the advanced rot, but in exceptional cases it may extend for 25 feet. The

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advanced decay is a yellow-brown crumbly rot with mycelium felts much less conspicuous than those of brown trunk rot (figure 15).

This rot normally occurs in the upper part of the trunk or in the top beyond the merchantable limit; consequently it is not economically so important as the others so far discussed, since when it does destroy merchantable volume it is the lower quality top logs that suffer most. The rot column is roughly cylindrical, following the shape of the heartwood and tapers cone-like at the ends. Seen in cross section at the ends of logs the rot is circular in area.

Indications of decay. The perennial, bracket-like conks ranging up to 6 inches or so wide are readily recognized by the delicate rose color of the undersurface, with small, regular pores. The upper surface is hard, rough, zoned, and black in color (figure 15). No swollen or punk knots are associated with this decay.

Yellow-brown top rot is very difficult to detect in standing timber. While conks are not uncommon, they are so high up in the trees as to be easily overlooked and are often completely hidden by the branches. The decay enters through dead branch stubs, dead tops, and various wounds. Consequently spike-topped trees are often infected.

PITTED SAP ROT

This decay, which is very common in the sapwood of dead timber, occasionally occurs in the dead sapwood of basal wounds on a living tree. It is caused by the purple fungus (*Polystictus abietinus*).

Description of decay. The rot first appears as a faint yellowish tan color together with a softening of the wood. Next the outlines of small white pockets become visible. In the advanced stage these pockets, which are elongated parallel to the grain, are at first filled with whitish fibers, but later are empty. The pockets are separated by strips of apparently sound wood. This rot is confined to the dead sapwood around scars, usually fire scars, on the butts of trees. It causes little loss since most of the affected sapwood forming part of the butt swell slabs out in sawing.

Indications of decay. The thin, bracket-shaped annual conks are small with a hairy zoned upper surface of a grayish white color, becoming dirty white with age, and a purplish lower surface with conspicuous irregular pores which sometimes become broken up so the lower surface appears toothed. Aside from the conks there are

DECAYS OF SITKA SPRUCE

no other reliable indications of this rot except the presence of fire scars. It is not found so often in mature or overmature trees as in trees in second growth stands swept by ground fires.

DECAYS OF SITKA SPRUCE

THERE is much less loss from decay in Sitka spruce than in Douglas fir, and as a rule this species is quite free from decay up to an age of 200 years (7, p. 19).

RED RING ROT

This rot, caused by the ring scale fungus, is responsible for the most serious losses in Sitka spruce. The incipient stage appears as a reddish purple discoloration, readily apparent in contrast to the light pinkish brown or light reddish color of the normal heartwood. In the advanced decay the white cellulose pockets appear, but in the soft wood of Sitka spruce with the gradual transition from spring wood to summer wood in the annual rings there is little tendency to the formation of ring scale. The decay is not confined to any particular portion of the trunk. On the ends of logs it may appear as irregular crescent-shaped, ring-shaped, or circular areas of discoloration in the incipient stage or white pockets in the advanced stage, narrowly bounded by discoloration.

The decay enters the tree principally through dead branches and is indicated by conks and swollen knots, as described for Douglas fir, but observation seems to show that these are not developed so abundantly as in Douglas fir.

RED-BROWN BUTT ROT

This rot, caused by the velvet top fungus, is common. The incipient stage is first evident as pale yellow to lemon-yellow streaks or spires extending longitudinally beyond the light yellowish to reddish brown discoloration which characterizes the more visible incipient decay. In the latter stage a softening of the wood is apparent, but the wood is seriously weakened even in the first stage. The wood in the advanced stage is a red-brown carbonaceous mass which

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separates into rough cubes and can be easily reduced to a powder between the fingers. The rot is usually confined to the butt, ordinarily not extending higher than the first 16-foot log, and its presence is indicated by conks on the ground or on the tree and by basal scars through which the decay enters.

BROWN CRUMBLY ROT

The red belt fungus (*Fomes pinicola*) which causes this decay is the most common destroyer of dead and down coniferous timber in the entire region. Occasionally it does cause localized rot in living trees, entering through wounds. The incipient stage of the decay appears as a faint yellowish brown discoloration with a noticeable softening of the wood. The advanced stage is light reddish brown in color, crumbly and brittle, breaking up into rough cubes with mycelium felts in the cracks. The felts are not so large or abundant as those formed by the quinine fungus. This decay usually occurs as a butt rot in connection with a scar. The rot column is roughly cone-shaped and on the end of a log is more or less circular in area.

The perennial conks which are rather large—in extreme cases as much as 2 feet wide—vary from hoof-shaped to shelf-like. When young they have a smooth, dark red upper surface with a chestnut brown to reddish band around the margin, but with age the upper surface changes to gray or black and is distinctly zoned. The under-surface is creamy white with numerous fine, circular pores. Very young conks first appear as round, white or cream-colored, tough, corky masses, issuing from knots or wounds. Other than conks there are no reliable indications of this decay.

DECAYS OF ENGELMANN SPRUCE

THIS species (*Picea engelmanni*) suffers most commonly from red ring rot, brown trunk rot, and red-brown butt rot. Occasionally it is attacked by brown stringy rot.

DECAYS OF BALSAM FIR

IN this group of trees are included white fir (*Abies concolor*), lowland white fir (*A. grandis*), silver fir (*A. amabilis*), noble fir (*A.*

DECAYS OF BALSAM FIR

nobilis), and red fir (*A. magnifica* and *A. magnifica shastensis*). The balsam firs are quite susceptible to decay, especially lowland white fir and white fir.

BROWN STRINGY ROT

White fir is very badly affected with this decay caused by the Indian paint fungus (*Echinodontium tinctorium*), and this has been studied in detail by Meinecke (13). The other species are also attacked, but in very much lesser degree. In the Blue Mountain region of eastern Oregon, white fir is so badly infected that a cruising rule often used is to cull completely all trees over 22 inches diameter breast high and to reduce the estimate on this size and under by from 15 to 25 per cent, depending upon the condition of the stand. In other localities losses of 25 per cent or more in mature and over-mature stands are common. On some operations white fir is not cut because it is so defective.

Description of decay. A hidden stage commonly precedes the incipient stage from one to several feet. The first indication of the incipient stage is light brown or golden tan spots or larger areas of discoloration in the light-colored heartwood, which may be accompanied by small but clearly distinct radial burrows resembling somewhat very shallow insect burrows without the deposit of excrement. Those burrows are not easily detected on cross section. Next, rusty reddish streaks appear following the grain. Up to this time the wood seems strong and only very slightly, if at all, softened, but in reality it is so greatly weakened that when sawed into boards they may fall apart along the annual rings when dried. The incipient stage usually extends from 2 to 6 feet beyond the advanced stage. The light brown color intensifies, the wood softens, showing a decided tendency to separate along the spring wood in the annual rings, and then the wood becomes brown with pronounced rusty reddish streaks, fibrous and stringy (figure 22). The butt of the tree frequently becomes hollow.

This rot is not confined to any definite portion of the bole, and in older trees it frequently extends the entire length of the trunk in the heartwood running into the roots and larger branches. In cross section the rot is circular in area, commonly destroying all the heartwood and leaving only a shell of sapwood (figure 23).

DECAY IN PACIFIC NORTHWEST CONIFERS

Indications of decay. The perennial conks are quite conspicuous (figure 25). They range from a few inches to a foot or more in width and are hoof-shaped. The upper surface in old specimens is black, dull, rough, and cracked. The undersurface is grayish in color, level, and is thickly set with hard, coarse spines. In younger specimens the upper surface is lighter in color and the undersurface is light grayish to whitish with somewhat labyrinth-like pores, before breaking up into spines. The interior or context of the conk is a striking rusty red or brick-red color, and this rust color is often seen in the decayed wood. The Indians made a pigment from the substance of the conks. The conks are formed on the underside of dead branch stubs, and normally the rusty color runs from the decayed heartwood through these stubs or knots. The conks are commonly located on the middle or lower middle section of the trunk and are developed quite abundantly. A single conk indicates extensive decay.

Swollen knots do not form with this decay, but punk knots, in this case called rusty knots owing to their rusty red color, are common. They can not be seen from the ground and are indications of value in standing timber in the butt only, where they can be chopped into with an axe to show the rusty red color which appears first an inch or so back from the outer end of the branch stub. In felled timber, knots can be easily examined along the entire trunk and several should be chopped into, since the color does not show in all branch stubs within the decayed portion of the tree. In scaling, if the ends of a log do not show decay, from 3 to 4 feet on each side of a rusty knot should be considered cull.

Brown stringy rot frequently enters the trees through injuries, most important of which are fire scars, lightning wounds, and frost cracks; consequently a stand with an unusual number of injuries normally will have a high percentage of decay. In a decayed tree with a frost crack, the rot usually extends the length of the crack.

OTHER ROTS

Red ring rot occurs occasionally on the balsam firs, and the conks may form directly on the bark instead of appearing through branch stubs. Red-brown butt rot is again in evidence. Brown crumbly rot is sometimes found in connection with wounds. However, the amount

DECAYS OF WESTERN HEMLOCK

of loss caused by these decays is relatively insignificant. Red fir suffers material losses from brown cubical rot caused by the sulfur fungus. This decay usually centers in the lower part of the trunk. It may also occur on other firs (figure 20).

DECAYS OF WESTERN HEMLOCK

THIS species (*Tsuga heterophylla*) is subject to a large amount of decay, particularly in the Inland Empire region (17), but in western Oregon and Washington it is much more sound. The loss, which may amount to 30 per cent or more in a given stand, is largely the result of brown stringy rot caused by the Indian paint fungus (*Echinodontium tinctorium*).

BROWN STRINGY ROT

Description of decay. The incipient stage is not easy to detect, since the initial discoloration, which is preceded by a hidden stage, closely resembles the pale brown color, slightly tinged with red, of the normal heartwood. The wood first assumes a faint yellowish color which is sometimes intensified by the presence of small, hardly discernible brownish areas which later develop into the advanced stage. The extension of incipient decay beyond the advanced decay varies from 1 to 5 feet. In the advanced stage the wood is reddish brown to brownish yellow in color, sometimes with rust-colored areas, stringy and fibrous. Hollows commonly develop in the butt logs. It is important that all stages of decay be excluded from logs or lumber. When wood with the incipient or hidden stage is milled, the boards when dried check badly or fall apart completely. Lumber should be trimmed 2 feet beyond the last recognizable yellowish discoloration in order to eliminate all weakened wood. Brown stringy rot in older trees commonly extends throughout the trunk, leaving only the sapwood unaffected. In cross section the rot area is circular.

Indications of decay. The conks on western hemlock are similar to those on white fir (figure 25) and need no further description. A conk normally indicates considerable decay. An average-sized conk on the butt 16 feet of the trunk indicates that the first two 16-foot logs are cull. A conk higher up on the bole probably means that

DECAY IN PACIFIC NORTHWEST CONIFERS

the entire main portion of the bole is unmerchantable. A tree with several conks some distance apart is completely unmerchantable.

Trees without conks are not necessarily free from decay. Old conks may die and fall off, but in this case a discolored spot on the bark or the bole left by the decayed branch may be seen. Furthermore, the old conks can sometimes be found on the ground close to the tree. Rusty knots or branch stubs are excellent signs of decay. This rusty reddish color in the branch stubs or knots, the same color as the substance of the sporophore, indicates typical decay in the heartwood. It does not occur in every dead branch stub over the decayed area, but normally occurs in some of them and can be readily exposed with an axe. In big timber this method of detection is principally of value for felled trees. While most of the infections enter through dead branch stubs, some do come in through injuries, so that badly scarred trees are quite likely to be decayed.

OTHER ROTS

Red ring rot is occasionally found in western hemlock, and the conks are usually thinner and more shelf-like than those on Douglas fir. Red-brown butt rot sometimes occurs.

DECAYS OF MOUNTAIN HEMLOCK

MOUNTAIN hemlock (*Tsuga mertensiana*) is a tree that is rarely logged, hence little is known concerning the decays attacking it or their relative importance. Brown stringy rot and red ring rot are both known to occur in it.

DECAYS OF WESTERN WHITE PINE

THE loss through decay in this species (*Pinus monticola*), also known as Idaho white pine, is considerably higher than in any other pine in the West. The cull per cent varies from little or nothing in the younger age classes to 18 per cent or more in trees 200 or more years older (18, p. 8). There are three relatively common rots.

DECAYS OF WESTERN WHITE PINE

RED RING ROT

This decay causes most of the loss. The incipient stage appears as a reddish brown discoloration, very apparent in contrast with the normal, almost white heartwood. The advanced stage is essentially the same as in other conifers. The heartwood throughout the trunk may be attacked and, contrary to its habit in Douglas fir, the decay is often a butt rot confined to the first 16-foot log. On cross sections the ring scale is frequently evident.

The best indicators are conks and swollen knots, and the latter are often accompanied by resin flow. At some knots there are small, dark, knob-like to branch stub-like outgrowths from one to several inches long which when examined are seen to be made up of the familiar brown punky substance mixed with resin. These are positive indications of decay. According to Knouf (11, p. 56), in western white pine in north Idaho, red ring rot will extend 2 feet toward the top from a punk knot and 4 feet toward the butt. This tree is little logged in the Pacific Northwest; consequently there are no figures available on the relation of conks, swollen knots, and punk knots to the extent of decay. Since most infection enters through branch stubs, injuries can not be relied upon as indicators of rot.

RED-BROWN BUTT ROT

This decay is next in importance to red ring rot. The incipient and advanced stages do not differ essentially from these stages in other conifers, and the rot is confined to the butt of the tree. Conks occur either on the ground or on the tree at old basal wounds, such as fire scars (figure 26) which are the common point of entrance for the decay.

SPONGY SAP ROT

The root Fomes (*Fomes annosus*) causes this rot which attacks not only the heartwood but also the sapwood.

Description of decay. The incipient stage is a lilac or reddish discoloration with no other indications of a change in the wood. In the advanced stage small white pockets form in the spring wood of the annual ring. Except for small black spots which are common in

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the centers of these pockets, they much resemble those of red ring rot. These pockets run together, causing a separation of the annual rings and later forming masses of white or whitish yellow spongy fibers, with occasional black flecks. Hollows may be developed. The rot usually does not extend higher than 6 or 8 feet into the butt log and is frequently accompanied by heavy resin flow.

Indications of decay. The conks which occur on the base of the tree on the root crotches or attached to a partially exposed root are inconspicuous and usually hidden by the forest mold. They are very irregular in outline, thick, crust-like, or somewhat bracket-like in shape with a gray-brown upper surface and a white or yellowish white pore surface. The only indication of this rot, aside from the conks, is the basal resin flow.

DECAYS OF WESTERN YELLOW PINE

THE common name as used above includes both western yellow or Pondosa pine (*Pinus ponderosa*) and Jeffrey pine (*P. jeffreyi*). Commercially the two species are always considered as one. On the whole, western yellow pine is relatively sound; it is rare that the cull resulting from decay, even in an overmature stand, exceeds 2.5 per cent except on a limited area, and it is usually much less. Four fungi are responsible for nearly all the decay, but as yet no comparative studies have been made to determine their relative importance.

RED RING ROT

The incipient stage is first recognizable as a pronounced pink color in the heartwood which rapidly gives way to a red-brown, hence the names "red rot" and "red heart" are often applied to this stage of the rot when the wood is still hard and firm. Then the white pockets develop, although they may appear so sparingly that they are easily overlooked. On the ends of logs the decay may appear as a full circle, somewhat crescent-shaped or rather irregular in outline. There is also a decided tendency to ring scale (figure 27).

The conks issue through knots. Swollen knots are developed which aid in detecting the decay. Infections commonly enter through dead branch stubs; therefore wounds are not reliable indications of red ring rot.

DECAYS OF WESTERN YELLOW PINE

BROWN TRUNK ROT

The incipient stage of the decay is quite striking. It occurs as a red-brown or pronounced brown discoloration in the pale lemon to light orange-brown heartwood (2, pl. v). The discoloration is not uniform over the entire affected portion, but may appear on the radial or tangential (slash) face in broad bands of varying intensity or even intermingled with narrow bands of the normal light-colored heartwood. On the ends of logs on close examination the infected wood, circular in outline, presents a mottled appearance. The brown discoloration is bounded by a narrow band of pronounced pink or red color, particularly noticeable on a radial or tangential surface. At the upper limits of the incipient decay the discoloration becomes fainter until it finally disappears. The discolored wood seems to be hard, firm, and strong, but it is seriously weakened. The incipient decay may extend for many feet beyond the advanced decay. In fact, it has been known to run for 32 feet, or 16 feet in each direction from the point of infection, before the advanced stage developed. The advanced decay does not differ essentially from that described for Douglas fir.

The most reliable indicators of this rot are conks. On this host they are larger than on Douglas fir. A single conk indicates extensive decay in the tree, so that in cruising such a tree should be considered a cull, although when felled it may be found to contain a little merchantable volume. Infections enter through dead branch stubs and dead or broken tops; hence the latter indicate the possibility of decay in a stand where this rot is known to occur. Occasionally its presence may be detected by its appearance in the heartwood of a large broken-off branch.

RED-BROWN BUTT ROT

This rot has been described on Douglas fir. On western yellow pine it usually runs out within 5 or 6 feet above ground level and rarely extends higher than the first 16-foot log. The rot column is generally cone-shaped. Conks are certain indicators of the decay, but open or healed-over fire scars are also fairly reliable evidence, since infections mostly occur through such wounds.

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RED RAY ROT

This rot, also known as western red rot which is easily confused with red ring rot, is caused by a white-colored fungus (*Polyporus ellisianus*). While on the whole in this region it is not very important on living trees, it is the most common destroyer of western yellow pine slash, rotting the sapwood of cull logs, tops, and large limbs within a few years.

It attacks the heartwood of living trees. In the incipient stage the infected wood shows a reddish to brownish discoloration but is still firm. On the end of a log, areas may be seen radiating out from the main body of the decay like spokes from the hub of a wheel; hence the name red ray rot. In some cases the rot area may have a circular shape, since the spoke-like projections are not always developed.

In the advanced stage small white pockets are formed, separated by the firm discolored wood described above. These pockets are about the same size as in red ring rot, but have blunt ends and occasionally small black flecks in them. The pockets frequently run together in the direction of the grain of the wood, forming long white patches. As this tendency to form patches increases the decayed wood becomes soft, spongy, and moist, so that it can be pulled out with the hands from the ends of logs. Finally all the whitish fibers or cellulose are destroyed, leaving only reddish to dark brown wood which is so rotted that it crumbles easily between the fingers. In this region while the rot may occur throughout the trunk, it is usually a top rot, most common in broken-topped trees and extending 10 to 20 feet or more down from the broken top.

Indications of this decay are meager. The conks of the fungus have never been seen by the writer on living trees, but have been found only on stumps, down trees, and slash. They are small, white to cream in color, and irregular in shape, either appearing in crevices of the bark as short, thick, shelf-like projections on the sides of the logs or stumps, or as thick crusts on the underside of logs. The margins of the conks are smooth, but the remainder of the surface shows numerous tiny circular pores. The conks are annual and are quickly destroyed by insects. Infections enter through dead branch stubs and broken tops; consequently injuries to the top are practically the only clues to the presence of red ray rot.

DECAYS OF INCENSE CEDAR

DECAYS OF SUGAR PINE

THE decays occurring in sugar pine (*Pinus lambertiana*) are the same as those in western yellow pine, except that red ray rot has not yet been found in living trees. The resulting loss is also small. Brown trunk rot is responsible for most of the cull that does occur. Branch stubs and dead or broken tops are the usual infection points for this rot, and the conks developed are unusually large. Red ring rot has little tendency to ring scale in the soft sugar pine wood and spreads out more uniformly through the heartwood (figure 28). Red-brown butt rot commonly occurs in connection with fire scars.

DECAYS OF LODGEPOLE PINE

LODGEPOLE pine (*P. contorta*) is of relatively little commercial importance in the Pacific Northwest; accordingly there is not much known about the rots attacking it, except that on the whole little cull results. Red ring rot, brown trunk rot, red-brown butt rot, and red ray rot all occur in this host.

DECAYS OF INCENSE CEDAR

THERE are three decays in incense cedar, but practically all the loss in this species results from pocket dry rot, pin rot, or pecky cedar caused by the incense cedar fungus (*Polyporus amarus*) (4). An idea of the amount of timber rendered unmerchantable by pocket dry rot may be obtained from the fact that so common is the defect that, in cruising, it is the usual practice to cut estimates of overmature stands from 30 to 50 per cent on account of it. This leads to a distinct prejudice against incense cedar on the part of the lumber industry, and the tree is classed as an "inferior" species.

POCKET DRY ROT

This is a pocket rot, and the pockets elongated in the direction of the grain vary in length from one-half inch to about a foot. They are several times longer than broad, with rounded or somewhat pointed ends. In the incipient stage the wood in the pockets is at

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first firm and very faintly yellowish brown. This color deepens slightly and the wood becomes somewhat soft. The incipient stage extends but a short distance vertically beyond the advanced stage, and a distance of 2 feet beyond the last visible evidence will usually exclude all decay. The incipient stage is only faintly apparent, occurring as it does in pockets with the color in the very earliest stage differing but slightly, when at all, from the normal wood. An occasional pocket may occur several feet in advance of the main body of decay. The wood, even in an incipient pocket, is decidedly weakened, although the wood between pockets does not appear to be affected. The purplish coloration of the heartwood so often found in freshly cut incense cedar and which fades within a few days on exposure to light and air, is not an incipient stage of decay. Cedar colored in this way is absolutely sound.

The pockets in the advanced stage are filled with a dark brown, carbonaceous, crumbly mass, and the line of separation between the sound and decayed wood is very sharp. In some pockets small cobweb-like or felt-like masses of white mycelium occur. The pockets are separated from each other by what appears to be sound wood, although occasionally streaks of straw-colored or brownish wood may extend vertically between two pockets. This is especially noticeable between young pockets.

On the ends of the logs the pockets are circular, elliptical, or somewhat irregular in shape, with firm, normal-appearing wood separating them (figure 30). The rot column, which roughly follows the shape of the heartwood, is not confined to any definite portion of the trunk, but may extend from the butt to the upper limit of the heartwood.

Indications of decay. The annual conks, which at best are not at all common, during certain years are very rare. Issuing from knots, they usually appear in the fall or summer, but occasionally are found at other seasons. They are bracket-shaped with rounded tops (figure 31) or half bell-shaped. When young the conks are soft and mushy with a smooth, tan-colored top and a bright sulfur-yellow undersurface with numerous small pores. Later the conks become tough and cheesy, turning brown, and finally become dry and hard. However, they are usually so quickly destroyed by insects, birds, and squirrels that the last stage is rarely reached. Although conks are not common, an accurate indication of the place formerly oc-

DECAYS OF INCENSE CEDAR

cupied by a conk is supplied by a shot-hole cup (figures 32 and 33). These shot-hole cups appear as cup-shaped depressions below a knot, the depression being riddled with numerous fine holes. At first they have the color of the freshly opened bark of the tree, but later become weathered and gray with age. They are formed in the following manner: The soft, fleshy or cheesy conks issuing through knots are usually soon eaten by squirrels and larvæ (grubs) of insects. Some of these larvæ then bore into the bark of the tree where they are sought after by woodpeckers that chop out a cup-shaped depression in the bark, corresponding to the place formerly occupied by the conks. The depression is riddled with what appear to be numerous fine shot holes—actually the burrows of the insect larvæ. A conk or shot-hole cup on a tree always indicates that there is extensive decay in the heartwood. As a rule these occur at about 15 to 30 feet above ground level, but wherever they appear the heartwood is always unmerchantable from ground level to a height of 10 to 50 feet above the conk or shot-hole cup.

Fire scars are the most common points of infection for pocket dry rot, and by far the greatest amount of loss results from such infections (4, p. 44). Consequently a badly fire-scarred, overmature stand will have a relatively large amount of pocket dry rot, since nearly 70 per cent of fire-scarred trees become infected. Particular care must be used in scaling butt logs with an open fire scar at the base. Pocket dry rot of any consequence is rarely found in the dried out wood back of an open fire scar. The base of such a log is nearly always absolutely sound; the top may show the entire heartwood unmerchantable. It is quite possible then for the scaler to judge the decay as extending half way down the log from the top, giving the lower half full scale and considering the upper half unmerchantable. But invariably the rot begins just at the top of the fire scar and almost immediately spreads out over the entire radius of the heartwood. In other words, in a log with an open fire scar showing on the butt end and with no rot pockets there, but with pockets of dry rot on the top end, the decay should be considered as beginning at about the top of the fire scar and extending from there to the upper end of the log in practically the same degree and radial extent with relation to the heartwood as is shown on the top end.

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OTHER ROTS

Red ring rot is sometimes found in incense cedar, but in the aggregate the resulting cull is not of commercial importance. The rot is usually localized around knots or healed wounds. There is no discoloration indicating the incipient stage; consequently the rot is not apparent until the small white pockets are formed. Occasionally one of the brown rots, either pocket dry rot or some other form, follows red ring rot, working first in the small white pockets which are changed to a brown color. Wood so affected appears to be filled with small brown pockets separated by firm wood. The conks are rarely ever found but, when they do appear from old branch stubs or knots, are so small and inconspicuous that they can not be seen from the ground.

Red-brown butt rot occurs occasionally, although it has not yet been definitely established that this is caused by the velvet top fungus. The decay is commonly connected with fire scars. On the whole the resulting loss is small.

DECAYS OF WESTERN RED CEDAR

ALTHOUGH there is some loss from decay in western red cedar (*Thuja plicata*), there are no exact figures on the amount of cull, but estimates usually place this at from 4.5 to 30 per cent in different localities where the tree is commercially important.

YELLOW RING ROT

Description of rot. This decay, which is probably the most serious, is caused by the brown cedar *Poria* (*Poria weirii*). In the incipient stage there first appears a yellowish discoloration in the brown heartwood which remains firm. Next, the yellowish color intensifies and the wood softens. In the advanced stage the affected wood has a yellowish or brownish discoloration, is soft, and the annual rings separate, giving the wood a laminated appearance on the radial face (figure 24). This separation of the annual rings occurs because the spring wood decays readily while the summer wood is more resistant. Finally the decomposed wood is reduced to a brown crumbly mass and a hollow may form.

DECAYS OF PORT ORFORD CEDAR

Usually this rot is confined to the butt log, extending up 6 to 12 feet, but it may run higher into the trunk. The rot column is cone-shaped at its upper limit. On the ends of the logs the rot is circular or crescent-shaped, and before complete disintegration has occurred, that is, in the stage where the annual rings have separated, it is a typical ring rot.

Indications of decay. The conks of this fungus are light to dark brown, flattened crusts with stratifications or layers, showing that they are perennial. The substance of the conk is dark brown and the undersurface is light brown with numerous small pores. The conks on living trees are commonly on the root crotches (figure 24) and partially obscured by the duff. They are more abundant on the underside of down trees or logs, developing there in long layers. This decay commonly enters through fire scars which, together with other basal wounds, indicate that a tree has been exposed to infection.

OTHER ROTS

A red-brown butt rot, probably caused by the velvet top fungus, is not uncommon, particularly in western Oregon and Washington. A decay similar to pocket dry rot in incense cedar has been observed on several occasions, but the fungus causing it is unknown. Red ring rot is sometimes found, but, as usual in cedars, the discoloration of the incipient stage is lacking. In northern Idaho where western red cedar is not so thrifty and rapid-growing as on the Pacific Coast, considerable loss may result from red ring rot. From 2 to 30 per cent of cull, principally caused by this rot, has been found in trees ranging from 10 to 45 inches at diameter breast high, the amount of decay increasing with the size of the tree.

DECAYS OF PORT ORFORD CEDAR

THE commercial range of this tree species (*Chamaecyparis lawsoniana*) is so relatively isolated and restricted in area that little is known about its rots. A red-brown butt rot, cause unknown, occurs occasionally, while red ring rot sometimes attacks the heartwood.

DECAY IN PACIFIC NORTHWEST CONIFERS

DECAYS OF ALASKA CEDAR

THERE is nothing known concerning decay in this species (*Chamaecyparis nootkatensis*), which is not found in commercial quantities in the region.

DECAYS OF WESTERN LARCH

THIS tree (*Larix occidentalis*) suffers considerably from decay, the most serious of which is brown trunk rot caused by the quinine fungus. The scientific name of this wood destroyer (*Fomes laricis*), freely translated, means larch Fomes. The rot occurs throughout the trunk. A similar rot is also caused by the sulfur fungus. On this host neither of these rots differs essentially from its previous description (see pp. 24 and 25). Red-brown butt rot is again in evidence.

Red ring rot also causes considerable loss. In heartwood with a more decided brownish tinge than normal the discoloration indicating the incipient stage of decay is not readily apparent. Very large swollen knots are developed (figure 34), and the decayed section of the trunk often becomes irregular in shape so that it appears somewhat cankered, indicating that the fungus may actually be parasitic, attacking the living sapwood and causing deformation of the trunk. This possibility remains to be confirmed by careful study.

DECAYS OF WESTERN JUNIPER

THIS tree, *Juniperus occidentalis*, is not of high economic importance, although it is used to some extent for pencil wood. The chief difficulty against its more extensive utilization is the large amount of decay, most of which is caused by one fungus.

JUNIPER POCKET ROT

This decay, caused by the juniper Fomes (*Fomes juniperinus*), in the incipient stage is first visible as a light yellowish discoloration, which becomes more pronounced, the affected wood becoming whitish and soft, until finally the advanced stage is characterized

CONTROL OF DECAY

by hollow pockets with their long axes following the direction of the grain. The pockets are lined with yellowish white fibers. They are commonly placed one above the other and when they join long tubes result. In a large tree in the last stages of decay, several such tubes may develop which, on the end of the log, appear as somewhat circular to irregular holes.

The perennial conks, usually hoof-shaped, are not easily seen, because in color they blend somewhat with the bark and because they frequently appear in the concavities of the fluted basal portion of the trunk. When young the upper surface is brown with numerous cracks, but later it becomes deep brown to almost black and very rough (figure 29). The undersurface is light brown with a smooth, light yellow-brown margin. The pores, easily visible to the naked eye, are circular in shape. The substance of the conk is a pronounced reddish brown, except in the more recent growth where it is light brown. A tree with a conk as a rule is completely unmerchantable.

CONTROL OF DECAY

IN stands already mature and overmature considerable financial loss from decay can be avoided by accurate cruising, which must be based upon a thorough knowledge of decay and its indications in standing timber. Accurate cruising will prevent an underestimate of the loss through decay in a stand and a consequent heavier investment in operating equipment than the volume of timber warrants. It will also enable operations to be planned so that the timber with the most severe loss can be cut first.

After the trees are felled they should be bucked so as to secure the greatest merchantable volume and to leave all unmerchantable material in the woods. To do this requires sound judgment. One company operating in a very decadent stand of Douglas fir, by careful supervision of its felling and bucking operations, reduced the amount of defective timber at the mill from 18 to 10 per cent with a resultant material saving in logging and transportation costs.

Individual trees as components of the forest are relatively a low value commodity. Only the stand as a whole represents value of consequence, so that any attempt to apply direct methods of prevention or control of decay to the individual would be so expensive that

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by the time the tree was cut it would have cost far more than its stumpage value. Furthermore, decay once started in a living tree can not be stopped by any method known to science except by cutting out the decayed wood and a liberal margin of surrounding sound wood, then sterilizing the wound. This is possible for very valuable shade or ornamental trees, but can not even be considered for forest trees.

The control of decay in forest trees is economically so limited now that it is reduced to what can be accomplished by indirect measures when the stand is cut and, in addition, some measure of help through prevention of wounds. In the future, when thinning operations become practicable, it will be possible to remove decayed trees as soon as they appear as is now done in many European forests, saving the sound timber in such trees and reducing the chances for infection of the remaining stand.

But with the virgin, overmature, highly decadent stands so prevalent in the Pacific Northwest at present, effort must be concentrated on the control of decay in the future stands. As has been mentioned previously, a common point of entrance for decay is through wounds. Some decays are noticeably connected with certain kinds of wounds. Butt rots are commonly associated with fire scars. Man is most prolific in causing wounds on trees by his many operations in the woods, such as logging, road and railroad construction, blazing trails, and other activities, and by man-caused fires. Reasonable care to avoid unnecessary damage to trees and adequate fire protection will aid to some extent in reducing loss through decay. But apparently in many species the greatest amount of decay enters through dead branch stubs. At present nothing can be done about this, but in the distant future in the most highly valuable stands it may be possible to knock off the small dead branches early in the life of the tree so they can be grown over quickly, thus shortening the time during which the trees are exposed to infection and raising the quality of timber by reducing the size of the knots.

Observations on all species and detailed studies on a few have shown that in their youth trees are practically free from decay, but loss increases with advancing age. It is self-evident that decay can not start until heartwood formation begins, and observations on incense cedar and Douglas fir indicate that this does not occur until the trees are at least 25 years old. Theoretically, from that time on

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they are subject to decay. It then remains to be decided just when the increase in decay becomes serious. This determines the age at which the tree must be cut to avoid loss of economic importance. It was found (4, p. 34) in its optimum range that incense cedar remained relatively sound until 210 years of age was reached, but in the intermediate range, where the species was slower growing and less thrifty, cutting should occur by the time the trees were 165 years old to avoid serious loss. For Douglas fir on the better sites, loss from decay will be slight until 120 years has been reached. The relation of age to decay must be studied for all species of commercial importance so that the proper felling age for each can be determined.

There is a common statement in forestry literature that in over-mature stands loss in volume through decay is balanced by increase in volume through growth, or sometimes the more inclusive term deterioration has been used instead of decay. This statement, which has never been based on careful investigation, has been a source of comfort to owners of defective timber. However, it would seem from cursory examination of many stands in the Pacific Northwest that after a certain period in their life the yearly or periodic growth increment is more than offset by the yearly or periodic decay increment, resulting in a net loss in the stand. This seems particularly true of white fir and Douglas fir, and a study of the latter species showed that there was an actual net loss in increment from decay beginning as early as 215 years in the most highly defective stands. Of course exceptional stands do remain relatively sound throughout their life and have no such net loss.

While the rate of loss in volume through decay can be determined with some exactness, it is extremely difficult to ascertain the actual financial loss since so many interrelated considerations, other than the mere rate of decay, enter into this figure to make it decidedly complicated. The loss in volume is made up in part by growth so that net volume loss is less than the actual volume increase in decay. On the other hand, there is a quality loss in the older timber that can not be replaced, because decay usually is most extensive in the more valuable portion of the trunk. To offset the loss in volume and quality there is a probable increase in the value of stumpage and consequent closer utilization. The proximity to market has an important bearing, since some operations have a ready sale for low grade, partially decayed material which to others is a dead loss.

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The general condition of the market is highly important, because throwing timber on a low market may result in far greater financial loss than will the inroads of decay over a period of years. The decision as to whether or not defective timber should be cut at a given time is far from dependent on the rate of decay alone—the value increase may more than offset the volume decrease through decay, and each stand will demand individual consideration of all factors involved.

The prevention of decay in the future forest is relatively simple in those species growing in virtually even-aged stands where clear cutting is practised as is the case with Douglas fir west of the summit of the Cascade Mountains. The stand is clear cut to make way for the new stand. Even if decayed trees with conks are left standing they will do little if any harm (1), since under sound management the succeeding stand will in turn be cut before it has attained the age at which there can be an appreciable loss through decay. Removing decayed trees from mature and overmature stands in advance of logging to prevent the spread of decay, as has been suggested, does not seem advisable unless it can be done at a profit on the trees removed. The operation would be very expensive, it is not necessary for the protection of future stands, and its effect on lessening the increase in decay by reducing new infections in present stands would be doubtful unless the work was done over extensive natural units of area, such as entire watersheds.

In uneven-aged, pure or mixed stands managed on a selection system the problem is more difficult. In eastern Oregon and Washington the uneven-aged, mixed coniferous stand composed of varying amounts of western yellow pine, Douglas fir, white fir, lowland white fir, western larch, and lodgepole pine, with an occasional Engelmann spruce, is handled on a modified selection system of cutting. Trees are left that will have reached the age at which they are liable to extensive decay before time for the second cut. Consequently, all trees decayed at the time of cutting, particularly those with conks, should be removed to prevent spreading decay to the future stand. Trees left standing for the next cut should be free from open scars through which decay might enter. Therefore, scarred trees should be felled as far as possible, care exercised in logging to avoid wounding the reserve trees, and adequate fire protection given the growing stand. Red ring rot, brown trunk rot, and

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red-brown butt rot are important in western yellow pine, Douglas fir, western larch, lodgepole pine, and Engelmann spruce, and it must be considered that the same decay from one tree species is able to infect the others. When these species grow in mixture, to protect any one or all, it is necessary to remove all decayed trees. But brown stringy rot, so widespread in white fir and lowland white fir, is not found in any of the above species, except rarely in Douglas fir and occasionally in Engelmann spruce. If necessary, white fir and lowland white fir with brown stringy rot can be left without danger to other species, though of course they occupy space valuable for thrifty young growing stock, and they tend to increase the percentage of the less desirable species in the future stand.

In northeastern Washington over limited areas an uneven-aged, mixed coniferous stand is found made up of western white pine, western hemlock, Douglas fir, white fir, lowland white fir, western larch, western red cedar, lodgepole pine, and Engelmann spruce. Here again a modified selection system of cutting is employed, and the same principles should be applied to minimize the future losses from decay. Yellow ring rot, probably the most serious decay of western red cedar, is confined to that host, and brown stringy rot, so severe on white fir, lowland white fir, and western hemlock, is of no importance on the other species.

In southern Oregon western yellow pine, sugar pine, Douglas fir, incense cedar, white fir, red fir, and lodgepole pine, with an occasional Engelmann spruce, occur in uneven-aged mixtures of varying composition. The same principles apply as to the uneven-aged, mixed stands discussed. Pocket dry rot occurs only in incense cedar, while brown stringy rot is practically confined to white and red fir.

The control of decay is complicated and can be accomplished only through steady, long-time work in the application of suitable cutting methods. Furthermore, no arbitrary set of rules can be drawn up that will apply equally to all types and regions.

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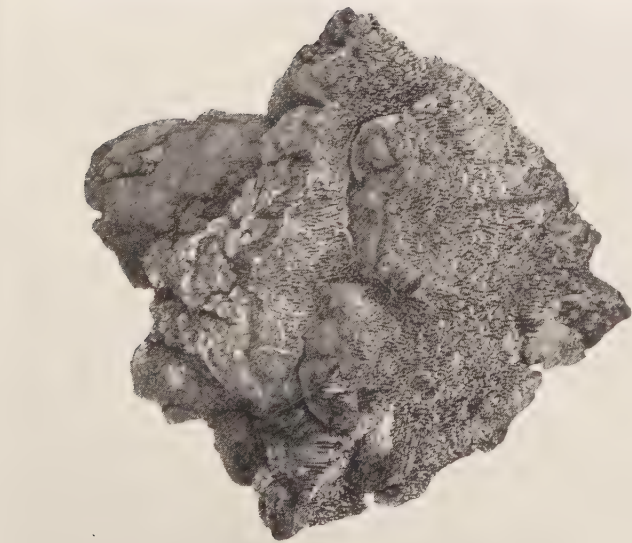


Figure 1. Sporophore or conk of the ring scale fungus (*Trametes pini*) from Douglas fir showing the rough, black upper surface and the irregular pores on the under-surface.



Figure 2. Burl on a Douglas fir. This does not indicate decay in the heartwood, although this tree was not felled because it was thought the presence of the burl indicated extensive decay.



Figure 3. A large Douglas fir left standing because of a fire scar in the butt and conks of the ring scale fungus (*Trametes pini*) on the lower part of the trunk.



Figure 4. Upper part of the trunk of the same tree, containing several sound, high grade logs.

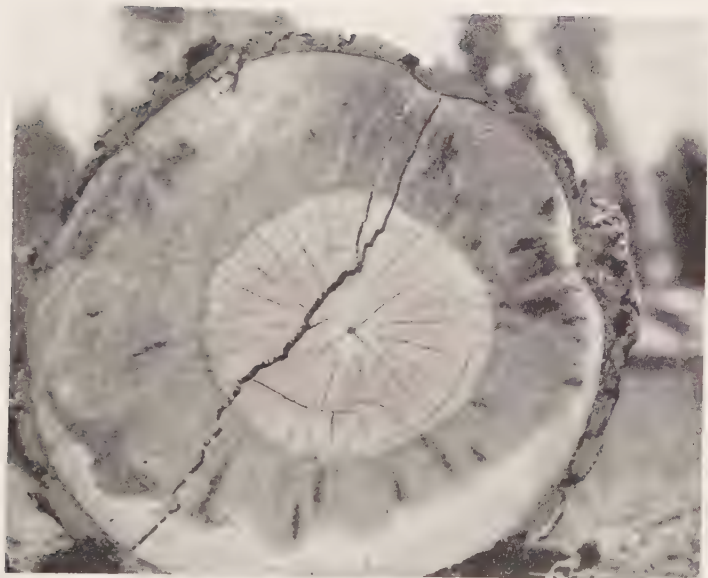


Figure 5. Blue stain in the sapwood of a western yellow pine log.



Figure 6. Radial section of Douglas fir wood showing the incipient stage of red ring rot caused by the ring scale fungus (*Trametes pini*). The narrow, darker-colored streak on the right is incipient decay.



Figure 7. End of a Douglas fir log with red ring rot. The upper portion of the log shows the discoloration characteristic of the incipient stage; and the lower portion, the ring scale character of the advanced stage. (Photographed by A. H. Hodgson.)

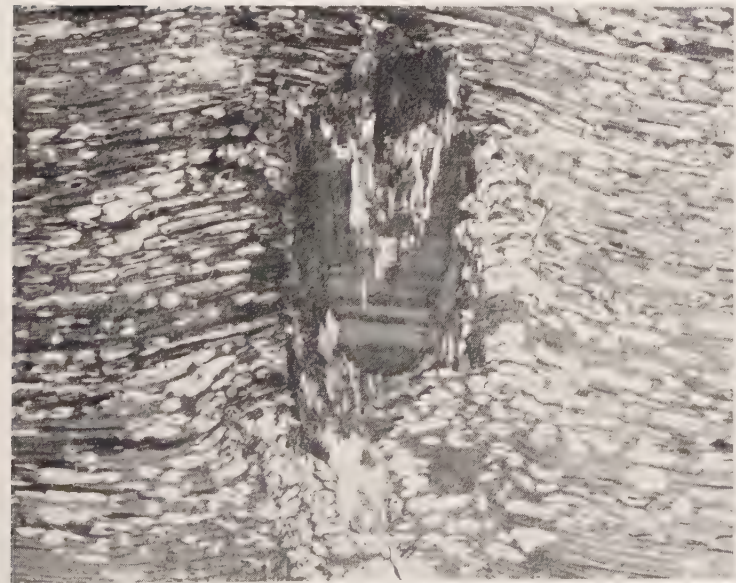


Figure 8. Radial view of the advanced stage of red ring rot in Douglas fir caused by the ring scale fungus showing a partly decayed knot.

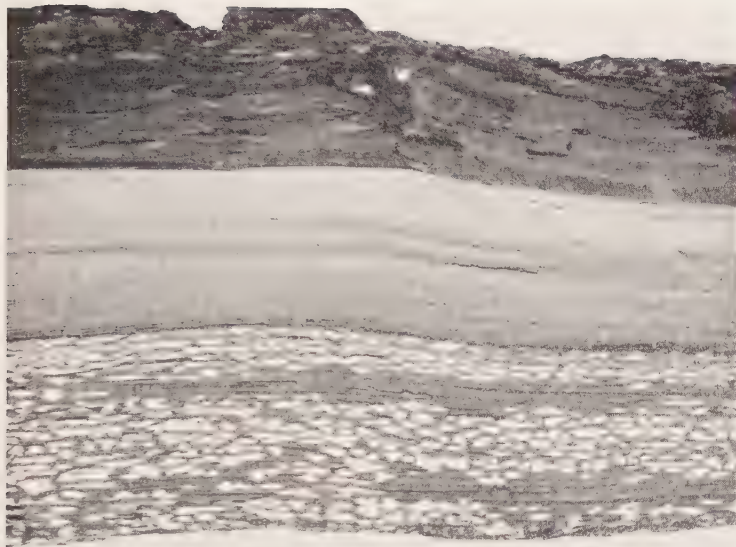


Figure 9. Radial view of Douglas fir wood showing red ring rot (on the left) caused by the ring scale fungus; sound heartwood, sapwood, and bark.



Figure 10. End of a Douglas fir log with red ring rot caused by the ring scale fungus (*Trametes pini*) showing a swollen knot. (Photographed by J. S. Boyce and R. E. McArdle.)



Figure 11. End of a sound Douglas fir log showing normal knots. (Photographed by J. S. Boyce and R. E. McArdle.)

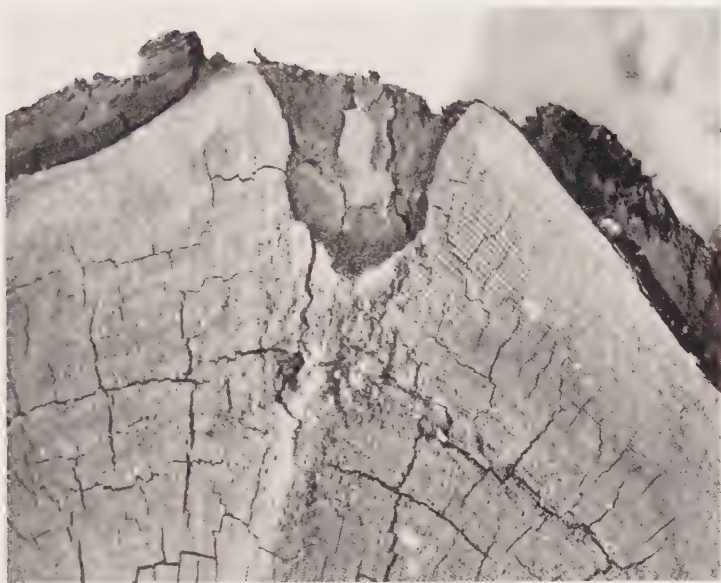


Figure 12. End of a Douglas fir log with red ring rot showing a swollen knot. This is an enlarged view of the swollen knot shown in figure 10. (Photographed by J. S. Boyce and R. E. McArdle.)



Figure 13. End of a sound Douglas fir log showing normal knots. This is an enlarged view of the knots shown in figure 11. (Photographed by J. S. Boyce and R. E. McArdle.)

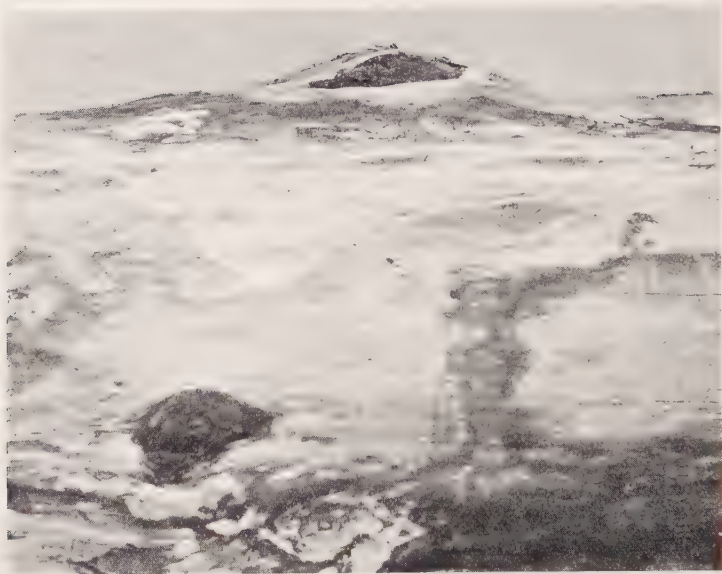


Figure 14. Side view of a Douglas fir log, from which the bark has been removed, showing swollen knots indicating red ring rot caused by the ring scale fungus. (Photographed by J. S. Boyce and R. E. McArdle.)



Figure 15. Cross section of a decayed top of a living Douglas fir showing yellow-brown top rot caused by the rose-colored conk (*Fomes roseus*) and the upper surface of a conk. Diameter inside bark of the section is 3.5 inches.



Figure 16. Swollen knots on a living Douglas fir indicating red ring rot in the heartwood caused by the ring scale fungus.

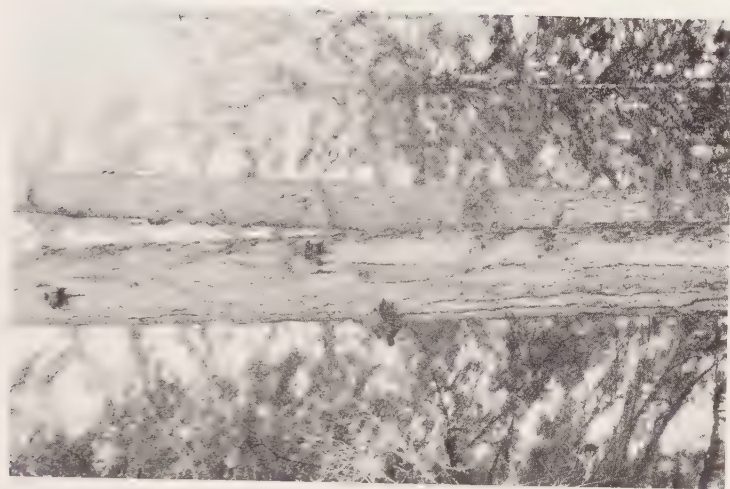


Figure 17. Conks of the ring scale fungus on a living Douglas fir indicating red ring rot in the heartwood. (Photographed by G. G. Hedgcock.)

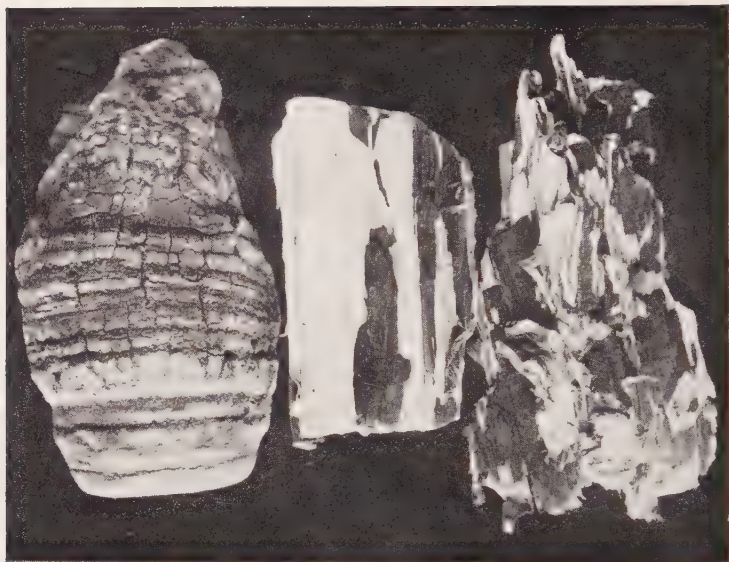


Figure 18. An old, chalky conk of the quinine fungus (*Fomes laricis*) causing brown trunk rot and decayed wood showing the white mycelium felts. (Photographed by E. E. Hubert.)



Figure 19. The heartwood of the butt of this Douglas fir has been completely destroyed by red-brown butt rot caused by the velvet top fungus (*Polyporus schweinitzii*). (Photographed by G. G. Hedgcock.)



Figure 21. A conk of the velvet top fungus (*Polyporus schweinitzii*) on the ground near the base of an infected tree. This fungus causes red-brown butt rot. (Photographed by H. J. Rust.)



Figure 20. Conks of the sulfur fungus (*Polyporus sulfur*) on the butt of a dead white fir. This fungus causes brown cubical rot. (Photographed by H. J. Rust.)



Figure 22. A broken white fir log with the heartwood completely decayed by brown stringy rot caused by the Indian paint fungus (*Echinodontium tinctorium*). (Photographed by G. G. Hedcock.)

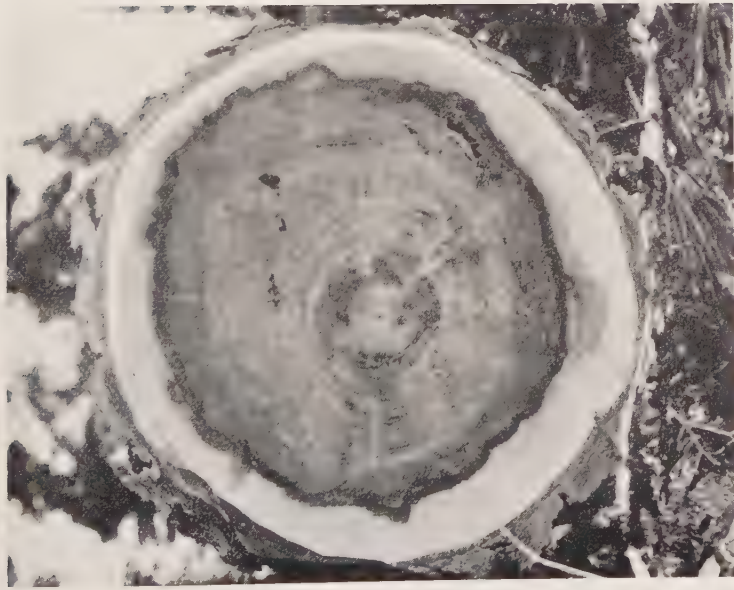


Figure 23. End of a white fir log with the heartwood completely destroyed by brown stringy rot caused by the Indian paint fungus (*Echinodontium tinctorium*).

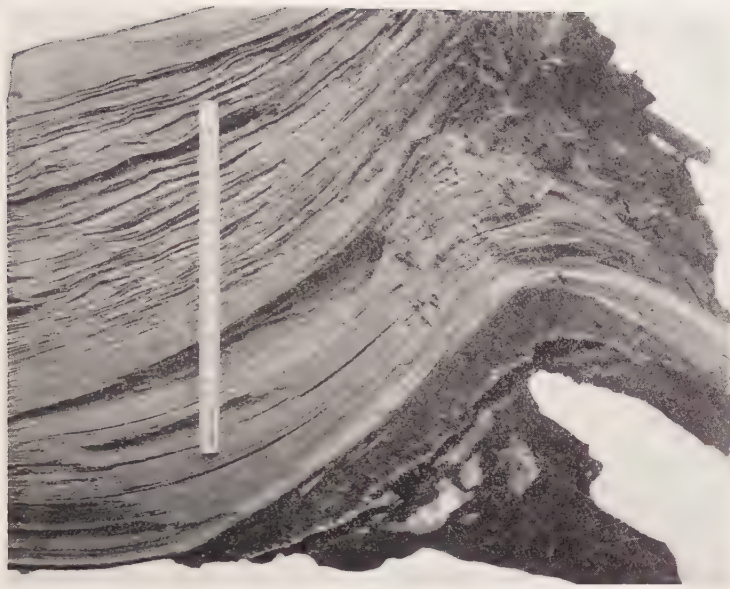


Figure 24. Radial section through the butt and root collar of western red cedar showing yellow ring rot in the heartwood caused by the brown cedar *Poria* (*Poria weirii*). The crust-like conk can be seen on the left-hand side of the trunk extending from about level with the ruler down the trunk to just beyond the root crotch. (Photographed by E. E. Hubert.)



Figure 25. Conks of the Indian paint fungus (*Echinodontium tinctorium*) on a living white fir. (Photographed by A. S. Rhoads.)



Figure 26. Conks of the velvet top fungus (*Polyporus schweinitzii*) in an old wound on the butt of a western white pine. The upper conk is fresh and growing, as indicated by the light-colored margin; the lower ones are old, dried up, and withered. (Photographed by J. R. Weir.)



Figure 27. End of a western yellow pine log with the heartwood destroyed by red ring rot caused by the ring scale fungus (*Trametes pini*). This illustrates the characteristic "ring scale" condition.



Figure 28. End of a sugar pine log with the heartwood completely affected with red ring rot caused by the ring scale fungus (*Trametes pini*). (Photographed by G. G. Hedgcock.)



Figure 29. Conks of the juniper Fomes (*Fomes juniperinus*) which causes pocket rot in the heartwood of juniper. The conk on the left is young; the one on the right is old and weathered.



Figure 30. End of an incense cedar log showing pocket dry rot, pin rot, or pecky cedar in the heartwood caused by the incense cedar fungus (*Polyporus amarus*).



Figure 31. Conks of the incense cedar fungus (*Polyporus amarus*) on a living tree. (Photographed by J. L. Mielke.)

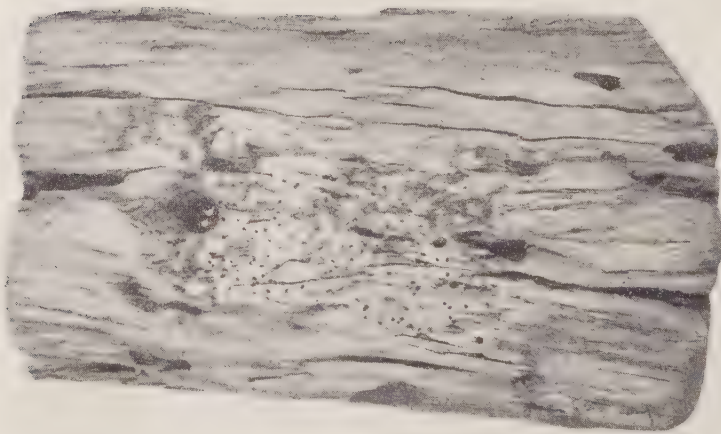


Figure 32. A shot-hole cup of the incense cedar fungus (*Polyporus amarus*). This indicates the place originally occupied by a conk and shows the knot hole in the bark through which the conk issued.

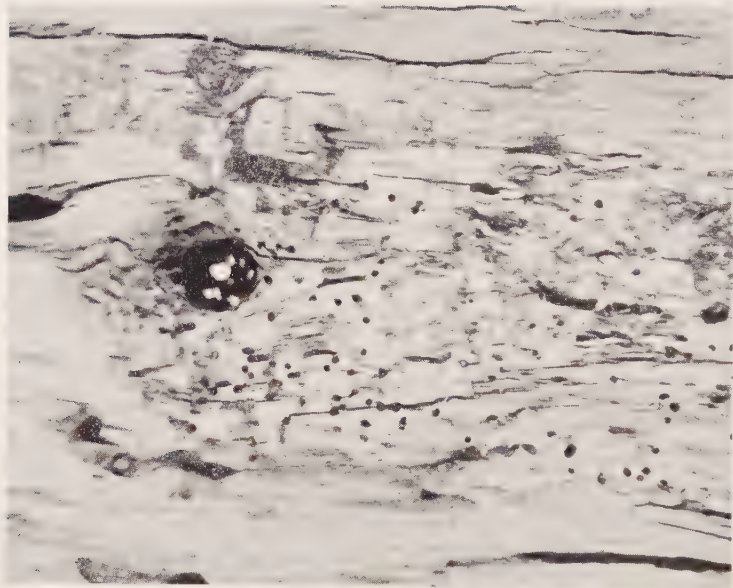


Figure 33. A detailed view of the shot-hole cup shown in figure 32.

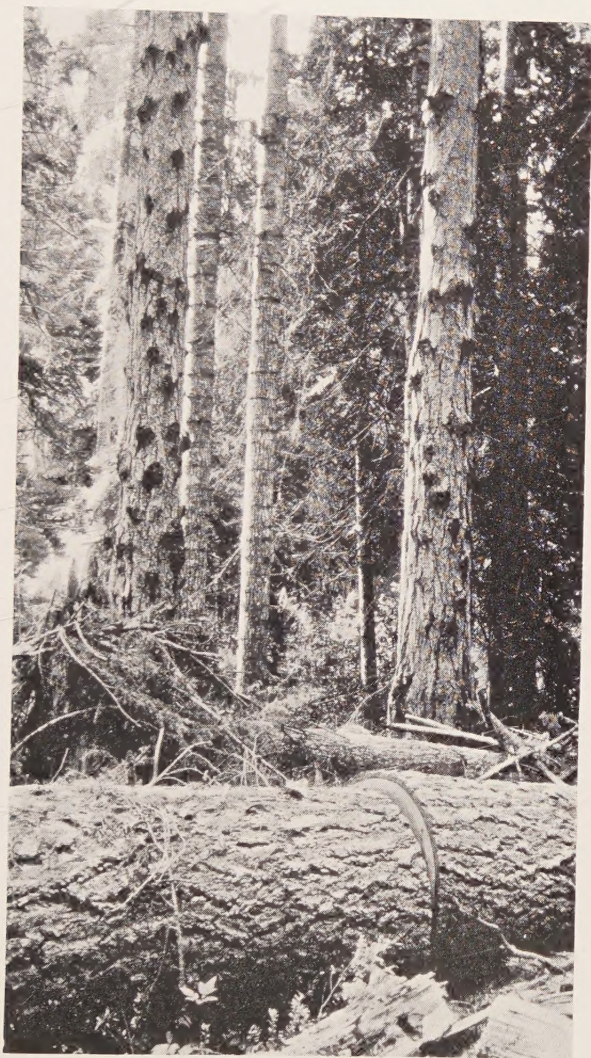


Figure 34. Swollen knots of the ring scale fungus (*Trametes pini*) on two living western larches indicating red ring rot in the heartwood. (Photographed by A. S. Rhoads.)

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